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Nutritional Importance and Processing Aspects of Pseudo-cereals

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Abstract—*Pseudo-cereals are considered very nutritious grains because of the presence of numerous bioactive components and high nutraceutical potential. The three well-known pseudocereal grains include quinoa (Chenopodium quinoa subsp. quinoa; Chenopodiaceae), amaranth (Amaranthus caudatus; A. cruentus; A. hypochondriacus; family: Amaranthceae) and buckwheat (Fagopyrum esculentum; Polygonaceae). These comprise a wide range of essential amino acids mainly lysine, methionine, tryptophan, arginine, and sulphur-containing amino acids in higher amounts than in other cereals. In amaranth and quinoa, amylopectin is present in a higher amount and is responsible for the greater viscosity, good freeze-thaw stability, higher swelling power, and higher water-binding capacity. These are major sources of different bioactive components comprising polyphenols, phytosterols, fagopyritols, saponins and many essential minerals. But, the bioavailability of these nutrients gets decreased because of the presence of certain anti-nutrients like phytates and tannins. The content of these anti-nutrients can be decreased by subjecting pseudocereals to various processing treatments like soaking, fermentation, puffing, germination and cooking so as to improve their organoleptic and nutritional characteristics. These processing treatments improve the nutritional value of pseudo-cereals by decreasing the amount of anti-nutrients and increasing the bio-availability of nutrients. Seeds of amaranth also known as "Inca wheat" are used as popped, toasted, sprouted, baked, ground into flour and cooked as porridge. Quinoa is rich in protein, fat, and fiber, with a good balance of essential amino acids and is processed by cooking, soaking and fermentation techniques. Buckwheat is usually milled into grits for breakfast food or consumed in roasted, boiled, steamed or baked form. Their flour or processed products can be utilized by the persons suffering from gluten allergy or celiac disease due to the absence of gluten in pseudo-cereals. Because of their high nutritional, medicinal and functional qualities, these have great potential to be utilized for the development of functional foods and prevention of various lifestyle diseases in different sections of society.*

Keywords*: Pseudo-cereals, nutritive value, bioactive components, anti-nutrients, processing treatments.*

1. INTRODUCTION

Pseudocereals are the class of dicotyledonous plants that resemble in function and composition with true cereals. These have no gluten content and therefore have wide application in gluten-free formulations. Pseudocereals are rich sources of high quality protein, fiber, minerals and also have bioactive and health promoting effects [1]. In human diet, cereals, pseudo-cereals and legumes are important sources of proteins, lipids, carbohydrates, vitamins and minerals. In addition to these facts, probiotic strains are used in cereals and pseudo-cereals for the fermentation process and develop new functional food products. These fermented food products are the rich source of the functional compounds such as antioxidants, dietary fibre, minerals, probiotics and vitamins [2].

In food processing industries, development of new functional foods is the attractive trend. Functional foods exert specific health benefits beyond their nutritional properties because of presence of nutraceutical components. Nutraceuticals are nutritional components having medicinal properties and play important role in maintaining well-being, enhancing health, modulating immunity and prevention of lifestyle diseases [3]. Functional foods impart great interest concern to the society and prevent or delay the number of age related problems such as osteoarthritis, Alzheimer's disease and diabetes [4]. Because of presence of numerous nutraceutical components, these have high nutritional, medicinal and functional qualities and have great potential to be utilized for the development of functional foods and prevention of various lifestyle diseases in different sections of society. This paper will reveal the brief knowledge of Nutritional importance and processing aspects of Buckwheat (Fagopyrum tartaricum L.), Amaranth (Amaranthus caudatus L.) and Quinoa (Chenopodium quinoa L.) as well as their utilization for development of functional food products.

2. BIOACTIVE COMPONENTS PRESENT IN PSEUDO-CEREALS

Buckwheat, quinoa and amaranth are rich source of compounds which include: flavonoids, phenolic acids, trace elements, fatty acids and vitamins which have known effects on human health like prevention and reduction of many degenerative diseases [5-8]. Fagopyritols, a type of soluble

carbohydrates is widely present in buckwheat seeds. Fagopyritol is a major source of D-chiro-inositol, a compound having valuable effects in patients with non-insulin dependent diabetes by improving glycemic control [9].

Buckwheat grains contain a variety of nutrients, the main compounds being: proteins, polysaccharides, dietary fibre, lipids, rutin, polyphenols, micro- and macroelements [10] these are a rich source of TDF (total dietary fibre), soluble dietary fibre (SDF), and are utilized for prevention of obesity and diabetes [11]. Buckwheat grains comprise abundant nutraceutical compounds and they are rich sources of B group vitamins [12].

Amaranth, containing huge amount of crude fiber, protein, tocopherols, squalene with cholesterol-lowering function, is a particularly important crop for developing countries [13]. Quinoa is the only available grain with natural amino acid balance in its protein. Its high quality is expressed by the content of histidine, isoleucine, leucine, phenylalanine, threonine, tryptophan, valine and mostly, lysine and methionine, the essential amino acids [14]. These grains are rich in minerals (K, Ca, P, Mn, Zn, Cu, Fe and Na), dietetic fibers and vitamins C and E [15].

Quinoa seeds are also an ample source of flavonoids, consisting primarily glycosides of the flavonols, kaempferol and quercetin [15]. Main phenolic compounds found in amaranth seeds are ferulic acid, caffeic acid and p-hydroxybenzoic acid [16]. Pseudocereal lipids an important group of biologically active components termed as phytosterols are present in pseudocereals. These cannot be absorbed in the human intestine and inhibit intestinal cholesterol absorption due to very similar structure to cholesterol thereby lowering total and low-density lipoprotein (LDL) cholesterol levels in plasma [17]. Quinoa seeds contain saponins at significant level. These are strongly bitter tasting, surface active compounds with a structure consisting of a steroid or triterpenoid aglycone and one or more sugar chains. Saponin levels vary within the range 0.01-4.65% with a mean value of 0.65% in different quinoa varieties [18].

3. PROCESSING TREATMENTS

Pseudo-cereals are subjected to various processing treatments so as to minimize the anti-nutritional components and improving the nutritional quality of pseudo-cereals. Various processing treatments available in literature are explained in following subheading.

3.1 Fermentation

Pongrac, Scheers [19] studied the effects of hydrothermal, processing and germination on Fe speciation and Fe bio-accessibility to human intestinal Caco-2 cells in Tartary buckwheat and found that groats contained the least Fe (23.8 ± 1.65 mg kg^{-1}) and the lowest amounts of Fe^{2+} (8%). Grains and sprouts had comparable Fe concentrations (78.2 ± 2.65 and 68.9 ± 2.73 mg kg^{-1}) and similar proportions of Fe^{2+} (15% and 18%). The main chelating agents for Fe in Tartary buckwheat material were phytate and citrate. Phytate was present in lower amount in sprouts, thereby increasing the bioavailability.

Carciochi, Galván-D'Alessandro [20] studied the influence of fermentation and germination time on the levels of antioxidant compounds (tocopherol isomers, ascorbic acid and phenolic compounds) and antioxidant activity of quinoa seeds. Fermentation was carried out naturally by the microorganisms present in the seeds or by inoculation with two Saccharomyces cerevisiae strains (used for baking and brewing). Total tocopherol and ascorbic acid contents were significantly increased ($p \leq 0.05$) after 72 h of germination process in comparison with raw quinoa seeds whereas fermentation caused considerable decrease in both types of compounds. Phenolic compounds and antioxidant capacity were found to be improved using both type of bioprocesses, and this effect more noticeable for germination process. Therefore, fermentation and germination proved to be the most appropriate techniques for producing ingredients enhanced with health-promoting antioxidant compounds by natural processes.

3.2 Popping

Amare, Mouquet-Rivier [21] evaluated the effect of popping and fermentation on protein quality of three different varieties of amaranth grains cultivated in Ethiopia. Amaranth grains have higher methionine, cysteine and lysine content than other cereals and legumes. Total essential amino acid, excluding tryptophan was 43% - 49%, which was higher than WHO reference pattern (31%). In-vitro protein digestibility decreased after popping by 8.3% - 17.1% and after fermentation by 4.8 - 7.5%.

Lara and Ruales [22] studied the popping of amaranth grain (*Amaranthus csaudatus* L.) and its effect on the functional, nutritional and sensory properties. By the use of different treatments, content of total starch, available and resistant starch were same. In starch, enzymatic degradation when carried out with α-amylase was 65% within 5–15 min. After treatments, total lysine content was 45.2–48.0 mg g^{-1} protein and crude protein was 15%. The *in-vitro* bioavailability of proteins present in popped grains obtained at 0.013 m^3 s^{-1} airflow and 14% grain moisture was above 84%. Sensory analysis revealed that grains have highest popping capacity with high crunch and expansion capacities.

Amare, Mouquet-Rivier [23] evaluated the effect of popping and fermentation on the chemical composition of three types of *Amaranthus caudatus* grains cultivated in Ethiopia. Proximate analysis of minerals, chemical composition and mineral absorption inhibitors were evaluated. The percentage of fat, ash, acid detergent fiber (ADF) and neutral detergent fiber (NDF) content increased by 12, 10, 15 and 67 %,

respectively. Whereas fermentation treatment increased protein, fat and ash content by 3, 22 and 14 % respectively.

Amare, Mouquet-Rivier [23] also studied the effects of processing methods on amaranth starch digestibility and predicted glycemic index. They compared the *in vitro* starch digestibility of processed amaranth seeds to that of white bread. Starch digestibility of cooked, popped and extruded amaranth seeds was similar to that of white bread (92.4, 101.3 and 91.2 respectively).

3.3 Soaking and Germination

Resio, Aguerre [24] studied factors affecting water absorption by amaranth grain during soaking. Water absorption in amaranth grain in plain water was determined at 30, 40, 50 and 60 °C by recording the weight increased in grain with respect to time. Hao, Wu [25] estimated the dual effects of slightly acidic electrolyzed water (SAEW) treatment on γ-aminobutyric acid (GABA) and rutin accumulation in germinated buckwheat. The results showed that SAEW treatment could promote the accumulation of GABA and rutin in germinated buckwheat. Also, it increased the glutamic acid decarboxylase (GAD) and phenylalanine ammonialyase (PAL) activity. Rutin and GABA reached 739.9 and 143.20 mg/100 g respectively.

Omary, Fong [26] reviewed the effects of germination on the nutritional profile of gluten-free cereals and pseudo-cereals and concluded that germination of these edible seeds has been shown to further increase nutrient content and to reduce antinutrients. These have great potential for the fortification and enhancement of gluten-free products. Kaur, Tanwar [27] estimated Vitamin C, total polyphenols and antioxidant activity in quinoa. The comparison was done to analyse raw seeds and industrially processed seeds in soaking and germination process. Analysis was carried out to analyze the effect on antioxidant activity by DPPH and FRAP, Vitamin C by N-bromosuccinimide (NBS) method and total polyphenols and flavonoids were determined colorimetrically. The results concluded that domestically processed seeds have higher vitamin C, total phenolic content (TPC), and total flavonoids content (TFC) and antioxidant activity as compared to the raw and industrially processed seeds.

De Ruiz and Bressani [28] studied the effect of germination on the chemical composition and nutritive value of amaranth grain. The sprouted grains were dried at 40˚C for 18 hr in hot air oven and grinded perfectly for proximate chemical analysis of thiamin, riboflavin, damaged starch and reducing sugars. There is no such change observed in protein, ash content and fiber on a dry weight basis. In germination process, there was increase in reducing sugars, total sugars, damaged starch and vitamins particularly riboflavin and ascorbic acid. Paredes-Lopez and Mora-Escobedo [29] studied the effects of germination on nutrient composition and color of amaranth seeds. Germination process of amaranth seeds was carried out at 0.92 a_w up to 72 hr. The percentage of crude protein, crude fiber and true protein increased whereas that of fat content decreased. In hunter color lab, the value of L get decreased and those for a and b were enhanced.

3.4 Cooking

Siwatch and B Yadav [30] reviewed the nutritional quality, processing and potential health benefits of pseudo-cereals and concluded that pseudo-cereals were subjected to various processing treatments like puffing, fermentation, germination and cooking to improve their organoleptic and nutritional characteristics. By the application of all these processing treatments, there was considerable reduction in anti-nutrients and improvement in availability or digestibility of nutrients. Pseudocereal grains are gluten-free. So, their flour or products can be used by the people who are suffering from celiac diseases.

Repo-Carrasco-Valencia, Encina [31] studied the effect of roasting and boiling of quinoa and amaranth seeds. There was considerable increase in bioavailability of iron, calcium and zinc after these processing treatments. Amount of bioactive components such as phenols, dietry fibre and minerals (calcium, zinc and iron) is present in higher amount than other cereals. Potential bioavailability of nutrients was estimated by dialyzability studies. Boiling of grains may increase in dialyzability of zinc, iron and calcium but had no significant affect on minerals after roasting.

Muyonga, Andabati [32] studied the effect of different heat-processing methods on physicochemical and nutraceutical properties in two main species, of amaranth grain i.e. Amaranthus hypochondriacus L. and Amaranthus cruentus L. They reported that gruels prepared from roasted grain have higher viscosity than the gruel prepared from raw and popped grain of amaranth. In both A. hypochondriacus L. and A. cruentus L., the order of the viscosity values was roasted>raw>popped. The viscosities were also generally lower for A. cruentus L. compared to A. hypochondriacus L. There was no significant difference between the raw samples for both A. hypochondriacus L. and A. cruentus L. in values of total flavonoid content (TFC), total phenolic content (TPC) and total antioxidant activity.

4. HEALTH BENEFITS

Pseudocereals are rich in various nutrients and also due to lack of gluten, these are considered best for the patients suffering from the gluten allergy [33, 34]. Many functional food products are prepared by the use of the pseudocereals. The component of pseudocereals recognized to reveals many health benefits include dietary fibre, proteins, lignans, essential amino acids, fatty acids, dietary fibre, minerals, phenolic compounds, vitamins etc [35]. Addition of pseudo-cereals in wheat flour improve the quality of protein content as lysine is present in higher amount in pseudocereals and have great potential to improves the Nutrional quality of bread [36].

In amaranth, squalene and tocotrienols are present in higher concentrations which are involved to lower down the low-density lipoprotein and blood cholesterol [37]. Buckwheat has been reported to be used as important ingredients for the new functional food development because of presence of functional components such as protein, flavonoids and phytosterols [38]. Presence of secondary metabolites such as rutin shows anti-inflammatory, anticancer, anti atherogenic and antioxidant activity in the buckwheat [39]. Protein extract is also useful to lower down the cholesterol and cancer effect in animals [8, 40]. Therefore, pseudocereals can be considered as potential source of bioactive components and can be utilized for development of functional food products which can prove useful in prevention of different lifestyle diseases such as cancer, diabetes, cardiovascular diseases and gastric disorders (Figure 1.).

5. VALUE ADDED PRODUCTS

Pseudocereals are widely used for preparation of nutrient rich gluten-free products such as pasta, bread and confectionary products. Ludena Urquizo, García Torres [41] developed fermented quinoa-based beverage in order to expand the traditional uses of quinoa and to provide new, healthier and more nutritious food products. Gambus, Gambus [42] utilized amaranth as an alternative gluten-free ingredient to increase the nutritional quality of gluten-free breads. Breads having acceptable level of amaranth flour were characterized by higher levels of fiber, protein and minerals.

Caperuto, Amaya-Farfan [43] studied the utilization of corn and quinoa for production of gluten-free spaghetti and found that products were moderately acceptable with a mild corn taste. Amaranth, quinoa and buckwheat were also used by Schoenlechner, Jurackova, and Berghofer (2004) to produce gluten-free pasta. Tosi, Ciappini [44] utilized whole amaranth flour to develop gluten free biscuits with higher protein content. Similarly, buckwheat, amaranth and quinoa were incorporated at

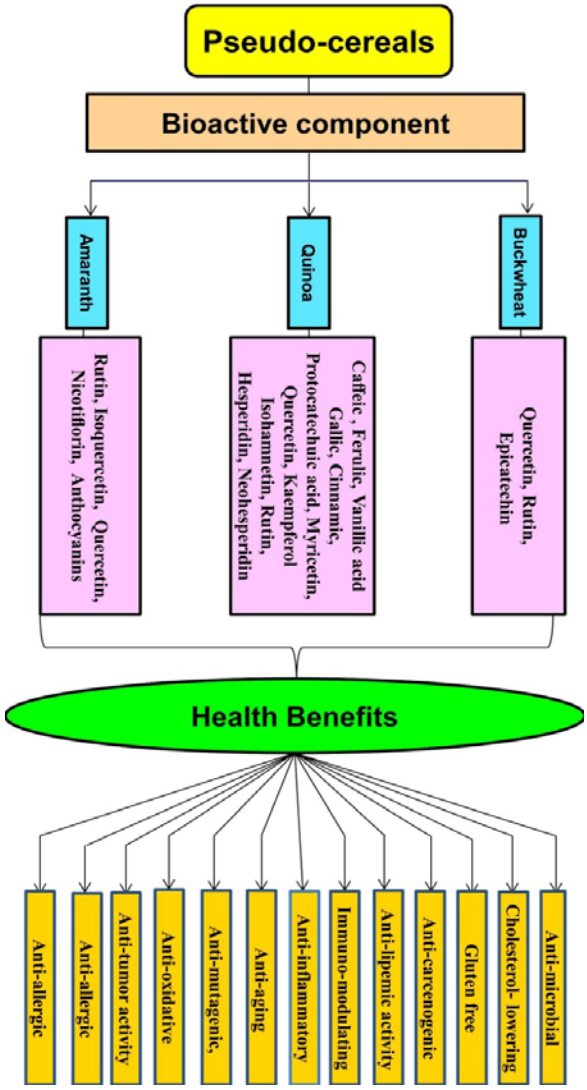

Figure 1: Bioactive components and health benefits of pseudo-cereals

levels of 25, 50, 75 and 100% in a gluten-free biscuit formulation. Crispiness of gluten free biscuit was reported in the order as buckwheat > quinoa > amaranth. Also, the biscuits containing buckwheat and amaranth were preferred by a sensory panel [45].

Amaranth based gluten-free bread fortified with iron has been successfully formulated by Kiskini et al [46]. Alvarez-Jubete, Arendt [47] replaced of potato starch with a pseudocereal flour for preparation of gluten-free breads with high content of nutrients like fiber, protein, iron, calcium, and vitamin E. these breads were reported to possess higher polyphenol content with increased in-vitro antioxidant activity. Further, loaf volumes of breads were found to be significantly higher for quinoa and buckwheat breads as compared with the control and breads were characterized by a significantly softer crumb.

There was no significant difference in the overall acceptability of the pseudocereal incorporated gluten-free breads as compared with control.

6. CONCLUSION AND FUTURE PROSPECTS

Pseudo cereals have great potential to be utilized as gluten free ingredients in for development of value added gluten free products. Beside their gluten free characteristics, these have been reported to possess high quality protein, ample quantities of fiber and minerals such as iron and calcium. Many bioactive compounds such as polyphenols, phytosterols, squalene and saponins with health-promoting effects are present in abundance in preudocereals. Processing treatments such as soaking, germination, popping, cooking and fermentation have been found to increase the nutritive value of these grains as well as the products developed by their incorporation. These can be widely utilized for development of gluten free processed products such as pasta, bread and confectionary products. There is an utmost need to commercialize the gluten free products based on pseudocereals as the availability of these products in the market is quite inadequate.

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